TCP/IP Addressing and Subnets

Binary/Decimal Review

In understanding how to convert binary to decimal and vice versa, it is helpful to review how the decimal system functions. The decimal system is based on the power of 10. The number 255 for example, literally means 2 hundreds plus 5 tens plus 5 ones or (2x100 + 5x10 + 5x1).

Where the decimal system is based on powers of 10, the binary system is based on the powers of 2. In an 8-bit binary segment, or byte, each bit has a value that ranges from (2 to the power of 0) to (2 to the power of 7). This range allows you to represent any number from 0 to 255 in binary. For example, 255 is the combination of 128+64+32+16+8+4+2+1, or all ones in binary which is written 11111111.

IP Address format

An IP address is 32 bits long and composed of four 8-bit fields, called octets. A 1 or 0 representing a bit. The octets are separated by decimal points. An example of an IP address, in binary format, is provided below.

| ←---------- 32 bits ----------→ |

Binary format: 11111111.11111111.11111111.00000000

Each 8-bit octet field can represent a number from 0 – 255, depending on the arraignment of 1's or 0's. This is because each bit, in the 8-bit octet field, actually represents a decimal number. For example, a one (1) in the left most position with all zeroes in the remaining positions represents decimal 128, i.e. 10000000. A one (1) in the right most position with all zeroes in the remaining positions represents decimal 1, i.e. 00000001. By using a combination of 1's and 0's, you can derive additional numbers from 0-255. In order to represent decimal number of 133, you would have the following combination of 1's and 0's:

```
 128   64   32   16   8   4   2   1
 /     /    /    /    /   /   /   /
1      0    0    0    0   1   0   1
```

Each 8-bit octet separated by a decimal uses the same method. For example:

Binary format: 10000001.01000001.00100001.00010001
represents
Decimal format: 129 . 65 . 33 . 17

This format is also referred to as "dotted decimal notation".

Quick Lab #1

1. Convert the following binary numbers to decimal format.
   a. 10101110 = _____
   b. 10110010 = _____
   c. 11001101 = _____
   d. 10101101.11100011.01011100.00110101 = _____
   e. 00001111.11100000.10101010.10001011 = _____
2. Convert the following decimal values to binary format.
   a. 250 = _____
   b. 137 = _____
   c. 192 = _____
   d. 154.92.105.122 = _____
   e. 207.134.189.224 = _____

Network and Host ID

Every IP address has a certain number of bits reserved for the network ID and a certain number reserved for the host ID. For example:

IP Address for 192.156.33.1 uses the first three octets (192.156.33) for the network ID and .1 for the host ID.

By this time, you are probably wondering, "How do you know which octets are used to represent the network ID and host ID?" Well, the Internet community also designated five IP address ranges as a certain "class" of address. The first 8-bit octet determines the class of address. The following charts shows the relationship between class, network range, binary format, network ID and host ID.

Class	Net Range	Binary format	Network ID	Host ID
A	1 - 127	**0**0000001 - **0**1111111	a.	b.c.d
B	128 – 191	**10**000000 - **10**111111	a.b	c.d
C	192 – 223	**11**000000 - **11**011111	a.b.c	.d

There are two additional classes (D and E) which are used for multicast group usage and experimentation. However, they do not follow the same rules as above and are beyond the scope of this training course.

When assigning network IDs and host IDs, the following rules apply:

a. Network ID cannot be 127. Reserved for loopback functions.
b. Network ID and host ID bits cannot all be 1's.
c. Network ID and host ID bits cannot all be 0's.
d. Host ID must be unique to the local network ID.
e. If your networks are connected by routers, a unique network ID is required for each wide area network connection.
f. A Network number is when all host bits are turned off (0).
g. A Broadcast address is when all host bits are turned on (1).

Assigning Network and Host IDs

A network ID is unique and is to identify a physical network. All TCP/IP hosts using the same physical network must be assigned the same network ID in order to communicate with one another.

A host ID must be unique to the network ID and identifies a TCP/IP host within a network. All TCP/IP hosts, including interfaces to routers, require unique host IDs.

The following table provides a range of host IDs for each address class:

Address Class	Beginning Host ID Range	Ending Host ID Range	Possible Number of Hosts
A	X.0.0.1	X.255.255.254	16,777,214
B	X.Y.0.1	X.Y.255.254	65,534
C	X.Y.Z.1	X.Y.Z.254	254

If you haven't noticed by now, the possible number of hosts per network is far greater then you'd ever need for one physical network. Additionally, if you have to assign a network ID for each wide area network connection, you'd be wasting numerous host IDs and require many more network IDs. Thus, a mechanism for making additional network IDs out of a single network ID came to the forefront. It is called "subnet" masking.

Subnet Mask

A subnet mask looks similar to an IP address. It is a 32-bit address that is used in conjunction with an IP address to distinguish the network ID from the host ID and determine if the destination host is local or remote. Each host on a TCP/IP network requires a subnet mask of some type. There are two types of subnet masks:

- **Default** - A default subnet mask is used on a TCP/IP network that is not divided into subnets. The default subnet mask you will use depends on the address class (A, B, C). The following chart depicts the relationship between address class, subnet mask in binary format, and dotted decimal notation:

Address Class	Subnet Mask in Binary Format	Dotted Decimal Notation
A	11111111. 00000000. 00000000. 00000000	255. 0. 0. 0
B	11111111. 11111111. 00000000. 00000000	255.255. 0. 0
C	11111111. 11111111. 11111111. 00000000	255.255.255. 0

If you notice, all bits corresponding to the network ID are set to 1 and the decimal value in each octet is 255. All bits corresponding to the host ID are set to 0.

- **Custom** - A custom subnet mask is used to divide a network into subnets. This is done by taking some of the host ID bits and using them for making additional network IDs. But first, let's see just how the internal process works for determing a network and host ID.

The internal process TCP/IP uses to find the network and host ID is identical Whether your working with a default or custom subnet mask. TCP/IP compares each bit in the IP address to the corresponding bit in the subnet mask to determine the network ID. The following bit combinations and results are provided below:

IP Address bit	1	1	0	0
Subnet Mask bit	1	0	1	0
Result =	1	0	0	0

Applying the rules above, the following example is provided:

IP Address (Class C)	192.129.130.2	11000000. 10000001. 10000010. 00000010
Subnet Mask	255.255.255. 0	11111111. 11111111. 11111111. 00000000
Result (Network ID)	192.129.130.0	11000000. 10000001. 10000010. 00000000
Host ID	192.129.130.2	11000000. 10000001. 10000010. 00000010

Let's say you just have the one Class C network (192.129.130.0) and need three more. However, you are told you'll have to do with what you have. So what are your alternatives? Use a custom subnet mask.

In subnetting, remember that a subnet ID must make use of contiguous, high-order bits. Therefore, the following subnet masks are what you have to work with.

Network (Class C)	192.129.130.0	11000000. 10000001. 10000010. 00000000
Possible Subnet Mask?	255.255.255.128	11111111. 11111111. 11111111. 10000000
Possible Subnet Mask?	255.255.255.192	11111111. 11111111. 11111111. 11000000
Possible Subnet Mask?	255.255.255.224	11111111. 11111111. 11111111. 11100000
Possible Subnet Mask?	255.255.255.240	11111111. 11111111. 11111111. 11110000
Possible Subnet Mask?	255.255.255.248	11111111. 11111111. 11111111. 11111000
Possible Subnet Mask?	255.255.255.252	11111111. 11111111. 11111111. 11111100
Possible Subnet Mask?	255.255.255.254	11111111. 11111111. 11111111. 11111110
Possible Subnet Mask?	255.255.255.255	11111111. 11111111. 11111111. 11111111

In determining whether or not the subnet mask is valid, you must refer to the rules previously provided, ie. Network and Host IDs cannot be all 0s or 1s.
Let's use an example to explain exactly how you determine whether you can use a specific subnet mask with an IP address. Using 2 bits, the following network combinations are possible:

00 - Invalid (Network ID cannot be all 0s)
01 - valid
10 - valid
11 – Invalid (Network ID cannot be all 1s)

IP Address (Host ID)	192.129.130.001	11000000. 10000001. 10000010. 00000001
Subnet Mask	255.255.255.192	11111111. 11111111. 11111111. 11000000
Network ID (Invalid)	192.129.130.000	11000000. 10000001. 10000010. **00**000000
IP Address (Host ID)	192.129.130.65	11000000. 10000001. 10000010. 01000001
Subnet Mask	255.255.255.192	11111111. 11111111. 11111111. 11000000
Network ID (Valid)	192.129.130.64	11000000. 10000001. 10000010. **01**000000
IP Address (Host ID)	192.129.130.129	11000000. 10000001. 10000010. 10000001
Subnet Mask	255.255.255.192	11111111. 11111111. 11111111. 11000000
Network ID (Valid)	192.129.130.128	11000000. 10000001. 10000010. **10**000000
IP Address (Host ID)	192.129.130.193	11000000. 10000001. 10000010. 11000001
Subnet Mask	255.255.255.192	11111111. 11111111. 11111111. 11000000
Network ID (Invalid)	192.129.130.192	11000000. 10000001. 10000010. **11**000000

Therefore, subnet mask 255.255.255.192 with a class C address of 192.129.130.0 has two valid subnets that can be used. They are:

Network ID	Beginning Host ID -	Ending Host ID	Total Hosts
192.129.130.64	192.129.130.65	- 192.129.130.126	62
192.129.130.128	192.129.130.129	- 192.129.130.190	62

- Note: IP address 192.129.130.127 and 192.129.130.191, in these instances must be reserved for Broadcasting for their respective subnets. The following example shows why:

IP Address (Broadcast)	192.129.130.127	11000000. 10000001. 10000010. 01**111111**
Subnet Mask	255.255.255.192	11111111. 11111111. 11111111. 11000000
Network ID (Valid)	192.129.130.64	11000000. 10000001. 10000010. **01**000000

IP Address (Broadcast)	192.129.130.191	11000000. 10000001. 10000010. 10**111111**
Subnet Mask	255.255.255.192	11111111. 11111111. 11111111. 11000000
Network ID	192.129.130.128	11000000. 10000001. 10000010. **10**000000

Since you require 3 subnetworks, the subnet mask 255.255.255.192 will not meet your requirements. You must try using a 3 bit subnet mask now. Notice the maximum number of hosts (62) that were possible using a 2 bit subnet mask. If the maximum number of hosts you need per subnet is greater then 62. You need not continue. Taking more bits away from the host ID will only reduce the number of hosts permitted per subnetwork.

To make it easier for you, we're providing a conversion chart on the next page. This chart can be used to determine how many subnets and hosts per subnet are available when working with a class A, B, and C network.

Conversion Chart

Class A network

The following chart lists the subnet masks already converted using one octet.

Number of of subnets	Required # of bits	Subnet Mask	Number of Hosts per subnet
0	1	Invalid	Invalid
2	2	255.192.0.0	4,194,302
6	3	255.224.0.0	2,097,150
14	4	255.240.0.0	1,048,574
30	5	255.248.0.0	524,286
62	6	255.252.0.0	262,142
126	7	255.254.0.0	131,070
254	8	255.255.0.0	65,534

Class B network

The following chart lists the subnet masks already converted using one octet.

Number of of subnets	Required # of bits	Subnet Mask	Number of Hosts per subnet
0	1	Invalid	Invalid
2	2	255.192.0.0	16,382
6	3	255.224.0.0	8,190
14	4	255.240.0.0	4,094
30	5	255.248.0.0	2,046
62	6	255.252.0.0	1,022
126	7	255.254.0.0	510
254	8	255.255.0.0	254

Class C network

The following chart lists the subnet masks already converted using one octet.

Required # of subnets	Required # of bits	Subnet Mask	Number of Hosts per subnet
Invalid	1	Invalid	Invalid
1- 2	2	255.192.0.0	62
3- 6	3	255.224.0.0	30
7-14	4	255.240.0.0	14
15-30	5	255.248.0.0	6
31-62	6	255.252.0.0	2
Invalid	7	Invalid	Invalid
Invalid	8	Invalid	Invalid

Quick Lab #2

1. What would be the default subnet mask for IP address 126.1.2.3?

2. What would be the default subnet mask for IP address 204.2.3.4?

3. 255.255.255.0 is the default subnet mask for what class address?

4. 255.255.0.0 is the default subnet mask for what class address?

5. What is the network ID for IP address 122.104.134.2 with a default subnet mask?

6. What is the network and host ID for IP address 192.156.20.2 with a default subnet mask?